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EFFECTS OF COLORANTS AND FLAVORANTS ON IDENTIFICATION, PERCEIVED FLAVOR INTENSITY, AND HEDONIC QUALITY OF FRUIT-FLAVORED BEVERAGES AND CAKE

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ABSTRACT

Four experiments were conducted to assess the effect of food color on flavor identification of noncarbonated beverages and to assess the interactive effect of food color and flavor levels on the perceived flavor intensity and hedonic quality of beverages and cake. Results showed that color masking dramatically decreased flavor identification of fruit-flavored beverages, while atypical colors induced incorrect flavor responses that were characteristically associated with the atypical color. In addition, the color level of beverages had significant effects on their overall acceptability, acceptability of color and of flavor, as well as on flavor intensity. The same results were shown with cake samples, with the exception that a significant interaction of color and flavor level was observed on overall acceptability. Correlational analysis on the subjective dimensions showed that the overall acceptability of both the beverage and cake products was more closely associated with ratings of flavor acceptability than with ratings of color acceptability. In addition, a test of the effect of colorant safety information showed that such information did not decrease any aspect of a product's acceptability.

INTRODUCTION

COLOR is an extremely important attribute of most food products because it usually influences the consumer's first judgment of the product and also provides sensory information which may interact with gustatory, olfactory, and textural cues to determine the overall acceptability of the product. Reports in the literature confirm the important role of color in taste recognition and taste intensity (Maga, 1974; Pangborn, 1960; Kostyla and Clydesdale, 1978), in detection and identification of food flavors (Moir, 1936; Kanig, 1955; Hall, 1958), and in acceptability of food products (Schutz, 1954; Foster, 1956; Maga, 1973; SIK, 1976). The recent concern of regulatory agencies about the safety of many food additives, especially artificial colors, increases the likelihood that some color additives will be reduced, eliminated, or replaced in future food formulations. Therefore, it is important that studies of the interrelationships among color, flavor, and acceptability of foods be conducted so that the effects of color on other sensory attributes can be adequately evaluated. The practical use of the knowledge obtained from such studies may enable food manufacturers to compensate for losses in product acceptability due to reduced color additives by altering other product ingredients, such as flavor additives.

The following experiments examined color/flavor interactions and how both color and flavor affect consumer identification and ratings of acceptability of food products. Foods in which colorant and flavorant ingredients could be varied independently were examined. In addition, the effects of colorant safety information on the judged acceptability of these products were examined.

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Table 1—Percentages of flavor responses given to each of the four color-masked beverages in Experiment I (N = 20)

Flavor response	Beverage			
	Grape	Lemon-Lime	Cherry	Orange
Grape	*70*	15	—	—
Lemon-Lime	15	*50*	40	50
Cherry	5	5	*30*	5
Orange	—	15	10	*20*
Strawberry	—	5	5	—
Raspberry	—	5	—	—
Banana	5	—	5	5
Gingerale	—	5	—	5
Other (sweet)	5	—	10	10

EXPERIMENT I

Method

To assess the effect of color-masking on flavor identification of fruit-flavored beverages, the following test was conducted. Four fruit-flavored, noncarbonated beverages (cherry, orange, grape, and lemon-lime) were prepared following manufacturer recommendations. All four beverages were manufactured and commercially marketed by the same company, under the same brand name. Samples were mixed 24 hr before testing using Natick tap water and stored at 4°C in glass containers.

Test subjects were 20 volunteer employees of this laboratory. All were members of a consumer taste panel, but were unaware of the purpose of these experiments. All subjects used in this and the following experiments were screened for normal color vision using the Ishihara Test for Color-Blindness (Ishihara, 1977). A criterion of 100% accuracy on the 11 test plates was adopted for inclusion of subjects in these studies.

Panelists were tested in individual sensory testing booths. To mask the color of the beverages, red fluorescent overhead lighting was used and red eye-goggles were worn by each subject.

The four test samples were presented individually, in random order, through the testing hood. Samples consisted of 40 ml of beverage presented in a 50 ml polypropylene plastic cup and served at room temperature (25°C). Subjects were instructed to taste each sample and identify the characteristic flavor of the beverage. No other information concerning the nature of the beverages was provided. Subjects were not restricted in their choice of flavor terms to describe the samples. Following completion of their task, but before leaving the laboratory, subjects were given samples of each of the four beverages under normal lighting conditions and were asked to identify each of the four beverage flavors.

Results & Discussion

An unexpectedly small set of flavor terms was used by subjects to describe the four beverages. Table 1 shows these flavor terms and the percentages of responses for each beverage. As can be seen, the percentages of correct identification ranged from 70% for the grape-flavored beverage to

20% for the orange-flavored beverage. The variation among these values is no doubt due to subjects' past experiences with these flavors as well as to the concentration of flavorant used in these products. However, these percentages may be compared to a 100% identification rate observed for the same beverages when tasted under normal viewing conditions before leaving the laboratory. The relatively large adverse effect of color masking on flavor identification observed in this test is of interest, considering the fact that differences in brightness between the beverages, as well as aroma cues were not eliminated by the red lighting or goggles.

EXPERIMENT II

Method

In order to examine the effect of atypical color on flavor identification of beverages, three fruit-flavored noncarbonated beverages and one flavorless noncarbonated beverage were used. The three flavored beverages were cherry, orange, and lime, each prepared by the same manufacturer of the beverages tested in Experiment I. The formulation of these three beverages was identical to that of their commercially-marketed counterparts, except that all color additives were eliminated from the dry base. The flavorless beverage was also prepared by the same manufacturer, and included all of the formulation ingredients typical of the brand of beverage, e.g., citric acid and ascorbic acid, except that both flavor and color additives were eliminated. This latter beverage base, when mixed with tap water and sugar according to manufacturer recommendations, produced a colorless, sweet beverage, but without any fruit flavor.

After preparing a sufficient quantity of each of the four beverages, each was subdivided into four one-liter volumes. Of these four, one was then matched in color to the commercially available, red-colored cherry beverage; one was matched to the commercially available, orange-colored orange beverage; and one was matched to the commercially available, green-colored lime beverage. Color matches were effected by adding predetermined amounts of FD&C red dye #40 (red), yellow dye #6 (orange), and blue dye #1 and yellow dye #5 (green) to the colorless mixes. Amounts used were determined in preliminary tests using a Hunter Colormeter (Hunter Lab Model D-25) to assess when a match was achieved. The last one-liter volume of each of the four test beverages was left colorless.

After preparation, all 16 samples were stored at 4°C for 24 hr before testing. Testing was conducted in the same test booths as used in Experiment I, but normal white-fluorescent lighting and normal viewing conditions were maintained. All samples were tested at room temperature (25°C).

Twenty-seven employees of the installation served as subjects. Samples were presented individually to each subject and in random order. Subjects were provided with a

Table 2—Percentages of flavor responses used to identify each of the 16 beverages in Experiment II (N = 27)

	Test beverages															
	Cherry flavored				Orange flavored				Lime flavored				Flavorless			
	Red	Orange	Green	Colorless	Red	Orange	Green	Colorless	Red	Orange	Green	Colorless	Red	Orange	Green	Colorless
Flavor responses																
Strawberry	7.4	3.7	7.4	7.4	14.8			3.7	11.1				22.2			
Raspberry	14.8	7.4	3.7	11.1	11.1			3.7	3.7				3.7			
Lemon		3.7	3.7	14.8		3.7	7.4	25.9	3.7		3.7	14.8			3.7	11.1
Lime			25.9	7.4	7.4	3.7	18.5	7.4	*14.8*	*18.5*	*48.2*	*44.4*			25.9	
Grape		3.7		3.7			3.7		7.4		3.7	3.7	3.7			
Apple	3.7	3.7		3.7			3.7			11.1			14.8	14.8	3.7	3.7
Cherry	*70.4*	*40.7*	*33.3*	*37.0*	14.8	3.7			18.5				7.4			11.1
Orange		18.5			*33.3*	*81.5*	*29.6*	*29.6*	3.7	40.7		3.7		22.2		
Blueberry			3.7		3.7										3.7	
Lemon-Lime		3.7	11.1	7.4	3.7		22.2	14.8	18.5	3.7	37.0	18.5			14.8	
Grapefruit							3.7	3.7							3.7	3.7
Apricot		11.1	3.7	3.7						18.5		3.7		7.4		3.7
Other (specify)	3.7	3.7	7.4	3.7	3.7	3.7	7.4	3.7		3.7	3.7	3.7	7.4	11.1	3.7	18.5
No flavor					7.4	3.7	3.7	7.4	18.5	3.7	3.7	7.4	*40.7*	*44.4*	*40.7*	*48.1*

Table 3—Percentages of flavor responses to each of the 16 beverages in Experiment II, collapsed according to flavors with similar color associations (N = 27)

	Test beverages															
	Cherry flavored				Orange flavored				Lime flavored				Flavorless			
Flavor responses	Red	Orange	Green	Colorless	Red	Orange	Green	Colorless	Red	Orange	Green	Colorless	Red	Orange	Green	Colorless
Cherry/Strawberry/Raspberry	92.6	51.8	44.4	55.5	44.7	3.7	—	3.7	33.3	—	—	—	33.3	—	—	11.1
Orange/Apricot	—	29.6	3.7	3.7	33.3	81.5	29.6	29.6	3.7	59.2	—	3.7	—	29.6	—	3.7
Lime/Lemon-lime	—	3.7	37.0	14.8	11.1	3.7	40.7	22.2	33.3	22.2	85.1	66.7	—	—	40.7	—
Lemon/Grapefruit/Apple	3.7	7.4	3.7	18.5	—	3.7	14.8	29.6	3.7	11.1	3.7	14.8	14.8	14.8	11.1	22.2
Blueberry/Grape/Other	3.7	7.4	11.1	7.4	7.4	3.7	11.1	3.7	7.4	3.7	7.4	7.4	11.1	11.1	7.4	14.8
No Flavor	—	—	—	—	7.4	3.7	3.7	7.4	18.5	3.7	3.7	7.4	40.7	44.4	40.7	48.1

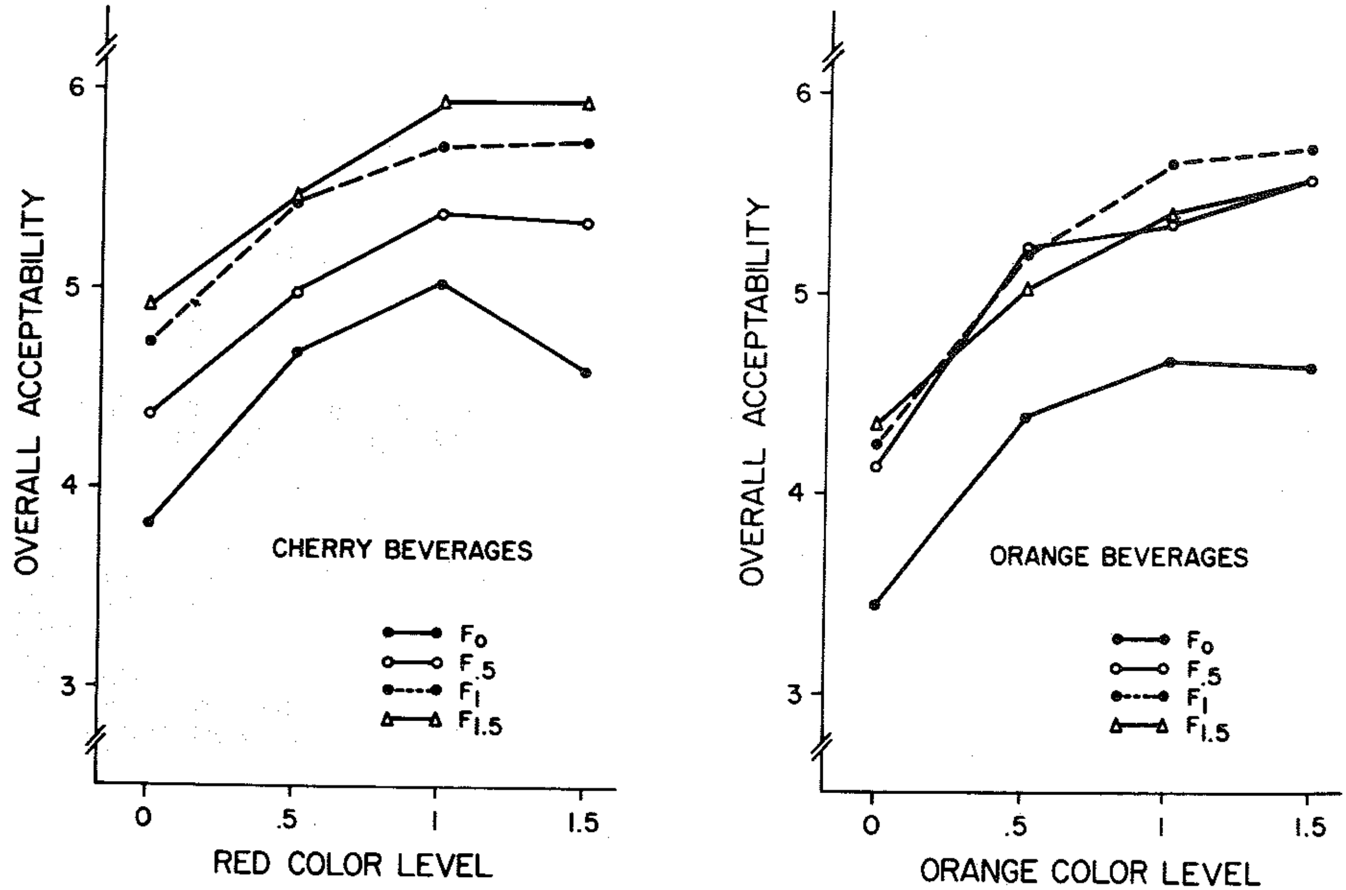

Fig. 1—Ratings of overall acceptability for 16 cherry beverage samples and 16 orange beverage samples. For the cherry beverages, mean points shown are based on the responses of 27 subjects each run twice. For the orange beverages, means are based on 25 subjects each run twice. Acceptability rating scale ranged from 1 (= dislike extremely) to 9 (= like extremely.)

checklist of 12 fruit flavors (compiled from the results of Experiment I) and asked to identify the flavor of each sample by checking the appropriate flavor from the list. Response choices of "no flavor" and "other" were also provided.

Results & Discussion

Table 2 shows the percentages of each flavor name used to identify each of the 16 color/flavor combinations of beverages. The percentages of the correct flavor choice for each of the four sets of beverage flavors are printed in italics. It is clear from these data that for the cherry and orange-flavored beverages, flavor identification was much better for the appropriately colored sample than for the inappropriately colored samples. For the lime-flavored beverages, the appropriate green-colored sample and the uncolored sample produced approximately equal flavor identification. Also, a large percentage of the subjects used the "lemon-lime" response to describe the flavor of the green-colored sample. The four beverages with "no flavor" were correctly identified as not containing any flavor with approximately equal percentages for the variously colored samples.

By combining all flavor categories in Table 2 which are normally associated with the same predominant color, Table 3 shows the resultant flavor categories and the collapsed percentage of responses. It is apparent from these data that inappropriate coloring of the four flavored beverages induced flavor responses that are normally associated with that color. For example, the orange-colored cherry-flavored beverage was most frequently mis-identified as having an orange or apricot flavor, the green-colored cherry-flavored beverage was most frequently mis-identified as lime or lemon/lime, and the colorless cherry-flavored beverage was most frequently mis-identified as lemon, grape-fruit or apple. Similar patterns or errors of identification can be seen in the inappropriately colored orange-flavored, lime-flavored and flavorless beverages.

EXPERIMENT III

Method

In order to assess how physical color level and flavor level interact and how each affects the acceptability of food products, 16 samples of cherry-flavored beverage and 16 samples of orange-flavored beverage were used. They were prepared by the same manufacturer of the beverages used in Experiments I and II. The cherry beverage samples consisted of each combination of four red color levels and four cherry flavor levels. The color levels were 0 (colorless), 0.5, 1, and 1.5 times the standard commercial red colorant concentration [L = 19.1, a = 27.6, b = 12.3 (Hunter Color Meter Hunterlab Model D25) for beverage with standard red colorant concentration]. The flavor levels were 0 (flavorless), 0.5, 1, and 1.5 times the standard commercial cherry flavorant concentration. The orange beverage samples consisted of the same 16 combinations of orange color [L = 28.3, a = 12.8, b = 18.5 for beverage with standard orange colorant concentration] and orange flavor levels. All samples were prepared with identical sugar concentrations in accordance with manufacturer recommendations.

Twenty-seven subjects rated each of the 16 cherry bever-

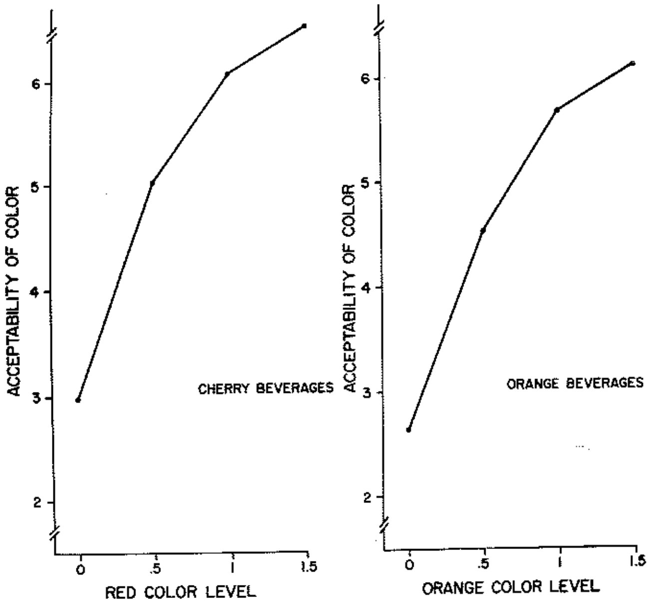

Fig. 2—Ratings of acceptability of color for cherry beverage samples and orange beverage samples. Rating are collapsed across the samples varying in flavor. Mean scores are shown. Color acceptability scale ranged from 1 (= dislike extremely) to 9 (= like extremely).

age samples. In a separate session, 25 different subjects rated the orange beverages. In each case, the samples were presented individually to each subject through a hood, in random order. Subjects did not swallow the samples and rinsed their mouths thoroughly with water between each sample. Subjects tasted and rated the samples at their own pace.

Subjects participated in this test twice, once after being given procedural instructions, and once after being given, in addition, colorant safety information which was printed in bold type and read:

> "ALTHOUGH ALL OF THE BEVERAGES WHICH YOU WILL SAMPLE ARE COMMERCIALLY PRODUCED, SOME CONTAIN DYES WHICH HAVE BEEN REPORTED TO CAUSE CANCER IN LABORATORY ANIMALS."

This condition was included to determine whether a warning of this type would affect subjects' perceptual judgments of the color, flavor or overall acceptability of the product.

The subjects judged four aspects of each of the 16 samples: overall acceptability, acceptability of color for a cherry-flavored (orange-flavored) drink, acceptability of cherry (orange) flavor, and intensity of cherry (orange) flavor. All of the ratings were made on 9-point category scales, with the exception of the flavor intensity rating, which included

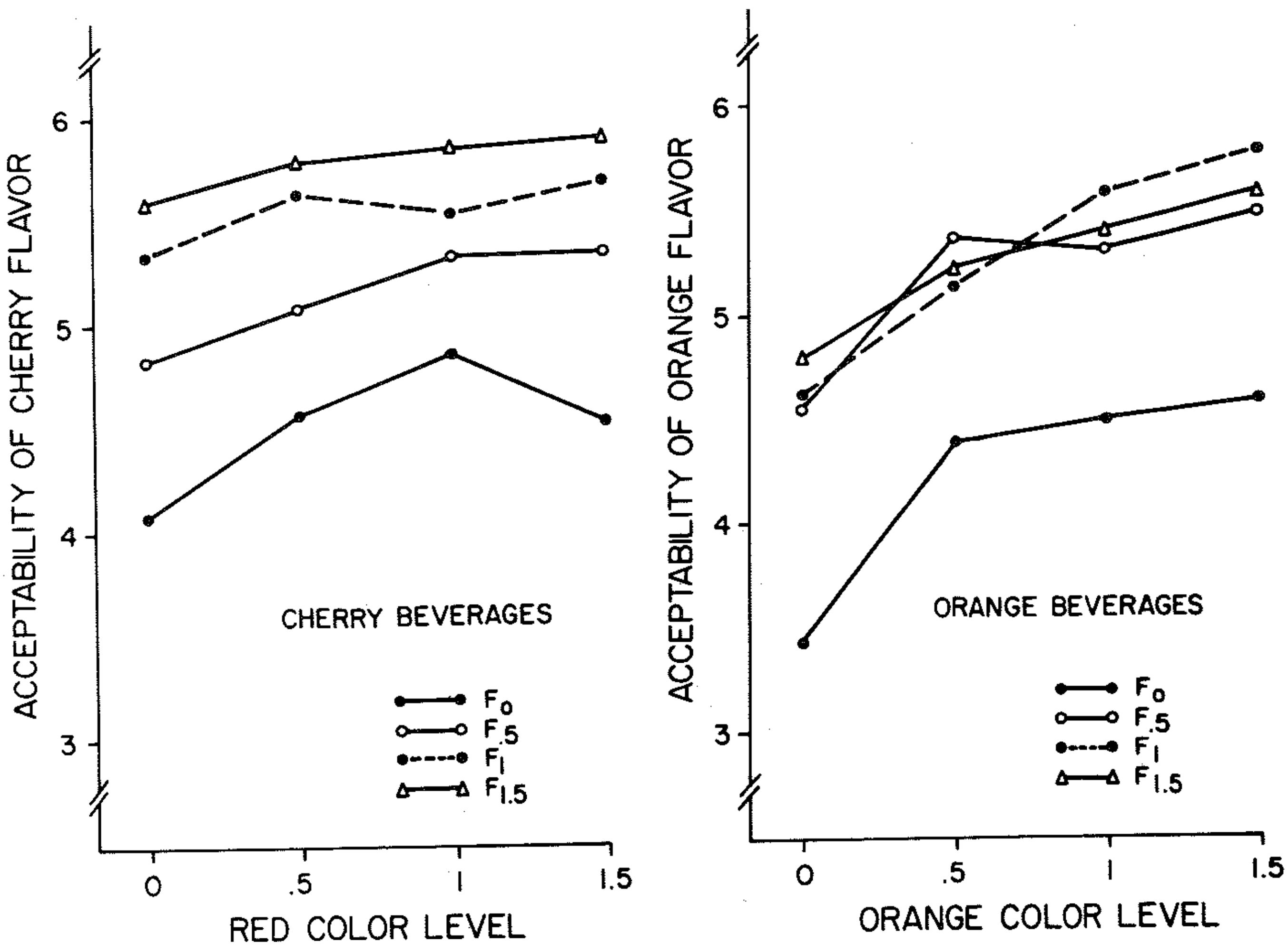

Fig. 3—Ratings of acceptability of flavor for cherry beverage samples and orange beverage samples. Flavor acceptability scale ranged from 1 (= dislike extremely) to 9 (= like extremely).

a zero response (for absence of flavor) in addition to nine points. The choice of *category* scales for this and the following experiment was due to the fact that the subjects had extensive previous experience with this type of scale.

Results & Discussion

Analyses of variance of the scores indicate that:

(1) **Overall acceptability** of the cherry beverages was significantly affected by both color level ($F = 14.89$, df = 3,78, $p < 0.001$) and flavor level ($F = 16.24$, df = 3,78, $p < 0.001$). Likewise, the overall acceptability of the orange beverages was significantly affected by both color level ($F = 40.13$, df = 3,72, $p < 0.001$) and flavor level ($F = 10.00$, df = 3,72, $p < 0.001$). These effects are shown in Figure 1. Overall acceptability generally increased as color increased and as flavor increased, although at the highest color levels and flavor levels a levelling off, and in one case a decrease, in acceptability occurred. Note that the reduction in acceptability produced by a decrease in the color level from the commercially marketed levels of color and flavor (C_1/F_1) could not be compensated by an increase in flavor level, at least for the color and flavor levels examined. However, if one looks at other color/flavor level combinations (e.g., $C_1/F_{0.5}$), then the decrease in acceptability produced by a reduction in color from this level can be compensated by increase in flavor level.

(2) **Acceptability of color** for both beverages was significantly affected by color level, as shown in Figure 2. (For the cherry beverages, $F = 62.08$, df = 3,78, $p < 0.001$ and for the orange beverages, $F = 96.77$, df = 3,72, $p < 0.001$). The ratings of color acceptability increased monotonically with increasing color level, with the most intense color being the most acceptable.

(3) **Acceptability of flavor** ratings for the cherry beverage were affected by flavor level ($F = 19.93$, df = 3,78, $p < 0.001$) and by color level ($F = 4.64$, df = 3,78, $p < 0.01$). Similarly for the orange beverage, the acceptability of flavor was significantly influenced by both flavor level ($F = 12.64$, df = 3,72, $p < 0.001$) and color level ($F = 24.45$, df = 3,72, $p < 0.001$) as shown in Figure 3. For the orange beverages, flavor acceptability increased as color increased although the effect of flavor level on flavor acceptability appears to be primarily due to the difference between the unflavored and flavored samples.

(4) **Flavor intensity** ratings were significantly affected by flavor ($F = 39.15$, df = 3,78, $p < 0.001$) in the cherry beverages and by both flavor ($F = 16.37$, df = 3,72, $p < 0.001$) and color ($F = 13.44$, df = 3,72, $p < 0.001$) in the orange beverages. These effects are shown in Figure 4. For the orange beverages, perceived intensity generally increased as color increased, even for the flavorless samples, suggesting a strong flavor-inducing effect of color.

The safety information was found to have no effect on the overall acceptability, acceptability of the color, acceptability of the flavor or the perceived flavor intensity of the beverages.

In addition to the effect of physical color and flavor

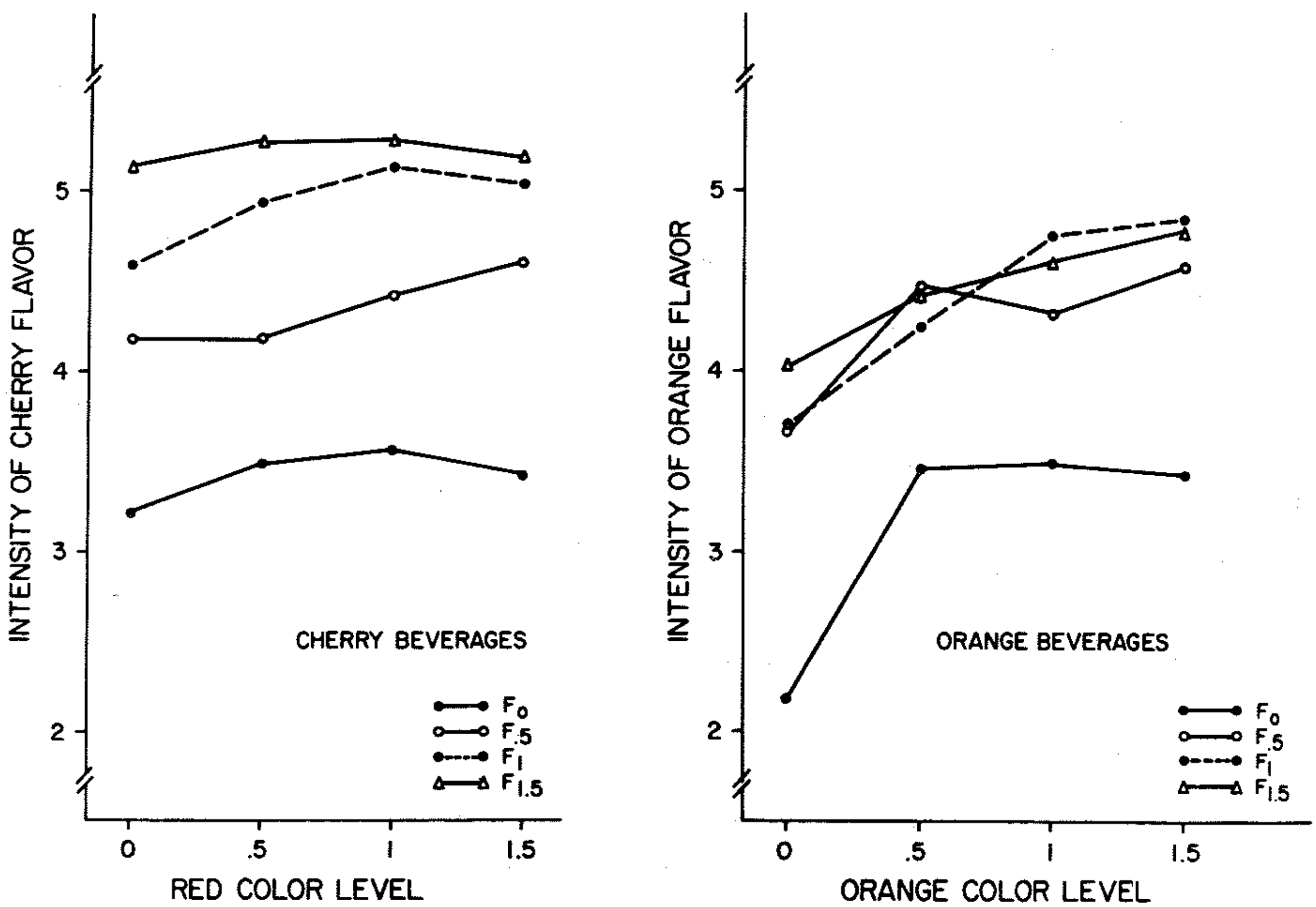

Fig. 4—Ratings of intensity of flavor for cherry beverage samples and orange beverage samples. Flavor intensity rating scale ranged from 0 (= no cherry (orange) flavor) to 9 (= extremely strong).

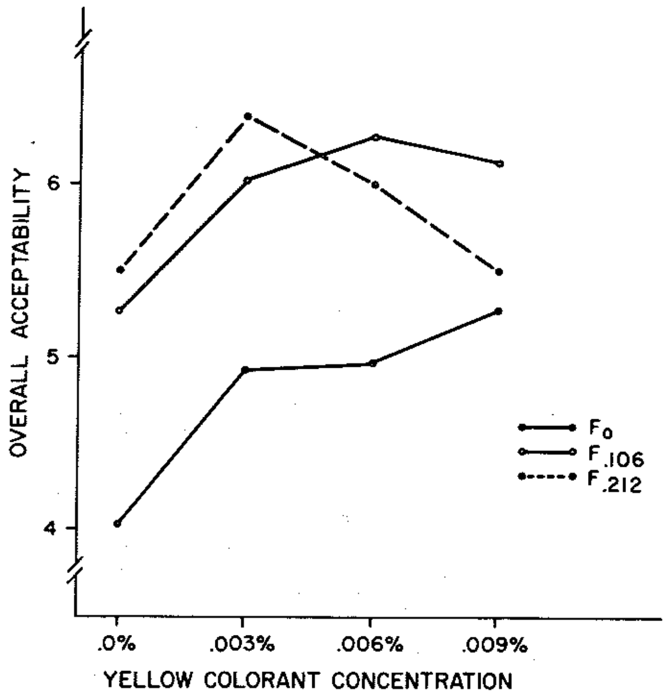

Fig. 5—Ratings of overall acceptability for 12 samples of cake varying in yellow colorant concentration and lemon flavoring concentration. Plotted points are mean scores based on 30 subjects run under normal (white fluorescent) lighting conditions. Acceptability rating scale ranged from 1 (= dislike extremely) to 9 (= like extremely).

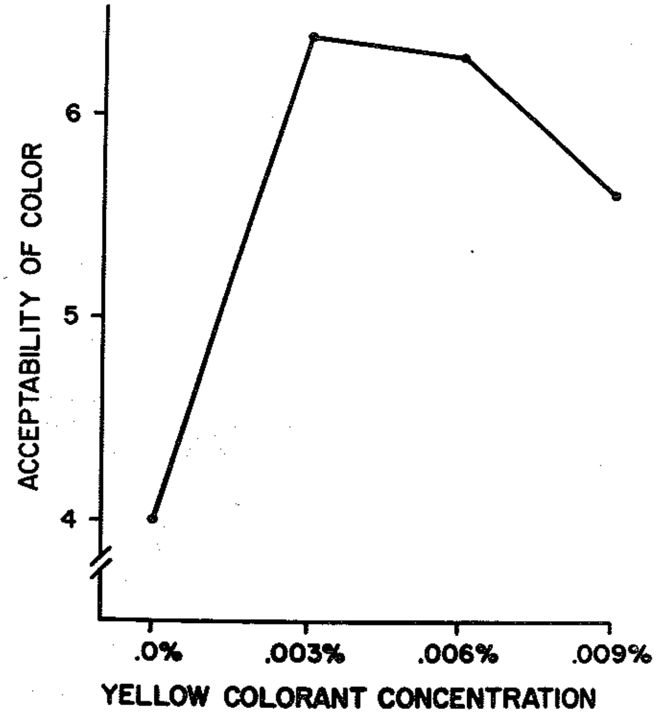

Fig. 6—Ratings of acceptability of color for samples of lemon cake. Ratings are collapsed across the samples varying in flavor. Mean scores are shown. Color acceptability scale ranged from 1 (= dislike extremely) to 9 (= like extremely).

levels on subjective responses to the beverages, the correspondence among the subjective responses are shown in Table 4. Pearson product-moment correlations among the four sensory ratings indicate that judgments of overall acceptability were most highly correlated with judgments of the acceptability of the flavor of the beverage. Correlations of overall acceptability with acceptability of color were lower but still sizeable, in keeping with the fact that a significant effect of color level on acceptability of flavor was found for both beverages. These data suggest that the overall acceptability of a beverage is more closely associated with its flavor than with its color.

EXPERIMENT IV

Method

In order to examine how color and flavor interact in a solid food system, the following experiment was conducted. The food was standard white cake to which were added varying amounts of yellow colorants (FD&C yellow #5 and #6) and colorless lemon oil flavoring. Twelve cake samples were prepared, consisting of each combination of four yellow color levels and three lemon flavor levels. The color levels were 0%, 0.003%, 0.006% (Hunter Color Meter readings L = 77.9, a = 3.2, b = 39.6), and 0.009% color (yellow #5:yellow #6 always 4:1). The flavor levels were 0 ml/g, 0.106 ml/g, and 0.212 ml/g lemon oil flavoring.

The samples were presented individually to each subject through a hood in random order. Subjects did not swallow the samples and rinsed their mouths thoroughly with water between each sample. They tasted and rated the samples at their own pace. Thirty subjects were run in this test under white (fluorescent) lighting conditions, and 30 subjects were run in a control test under color-masking red (fluorescent) lighting conditions.

The subjects rated four aspects of each of the 12 samples: overall acceptability, acceptability of color (for a lemon cake), acceptability of lemon flavor, and intensity of lemon flavor. (Subjects in the red lighting conditions did not judge the color acceptability of the samples.) The ratings were made using the same scales as were described for the beverage tests.

Results & Discussion

Analyses of variance of the scores obtained under the normal lighting condition, examining the effect of physical color level and flavor level, indicated the following:

(1) **Overall acceptability** was affected by a significant interaction ($F = 2.2$, $df = 6,174$, $p < 0.05$) between color

Table 4—Pearson product-moment correlations among the four subjective responses to cherry and orange-flavored beverages [all correlations were significant (N = 800, p = 0.001)]

	Acceptability of color	Acceptability of flavor	Flavor intensity
		Cherry	
Overall acceptability	0.376	0.864	0.625
Acceptability of Color		0.237	0.152
Acceptability of Flavor			0.723
		Orange	
Overall acceptability	0.583	0.887	0.603
Acceptability of Color		0.470	0.353
Acceptability of Flavor			0.663

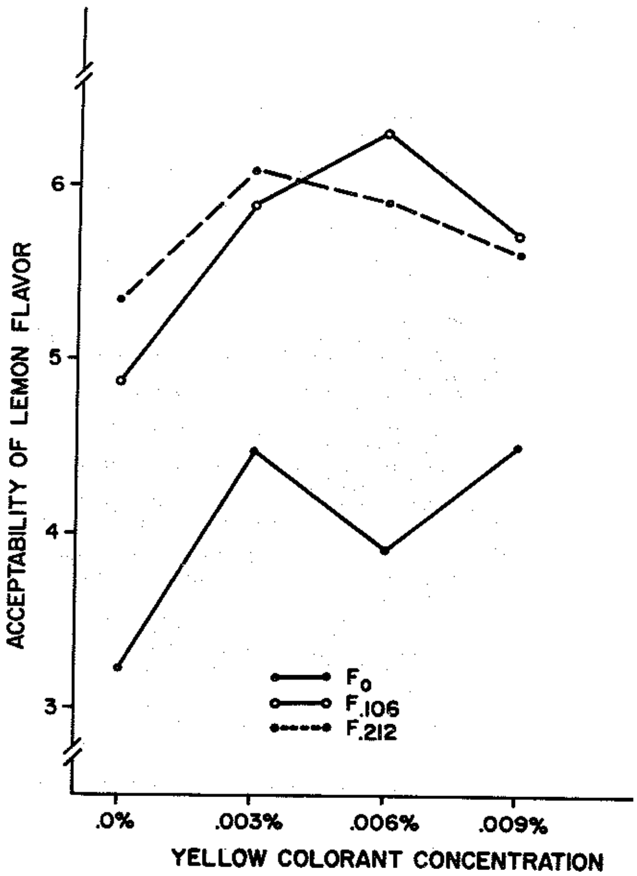

Fig. 7—Ratings of acceptability of lemon flavor for 12 samples of cake. Flavor acceptability scale ranged from 1 (= dislike extremely) to 9 (= like extremely).

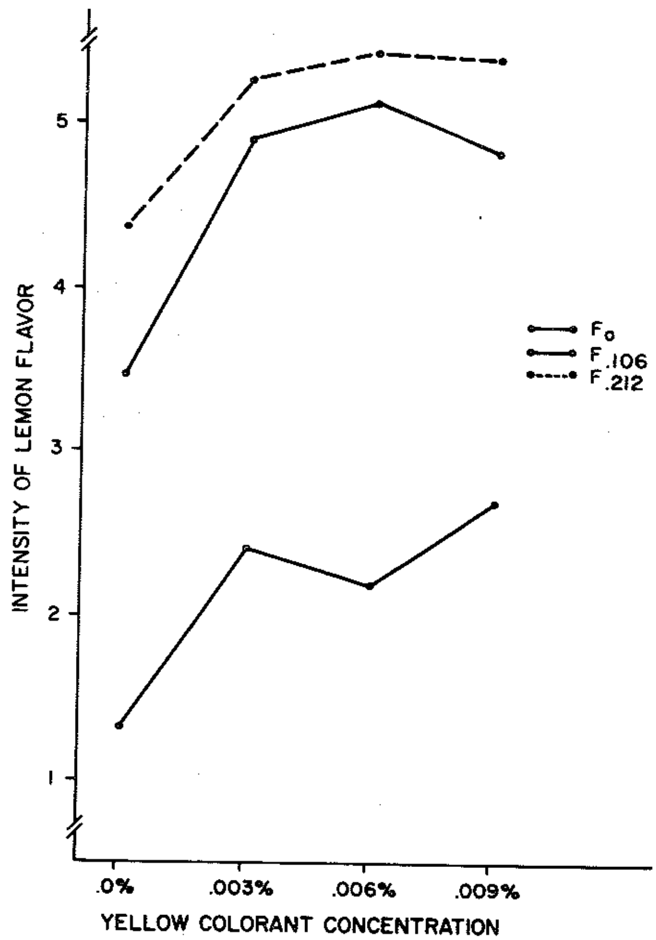

Fig. 8—Ratings of intensity of lemon flavor for 12 samples of cake. Intensity rating scale ranged from 0 (= no lemon flavor) to 9 (= extremely strong).

level and flavor level as illustrated in Figure 5. The flavorless sample increased in acceptability as the color increased, the 0.106 ml/g flavored sample peaked in acceptability at the 0.006% color level, and the 0.212 ml/g flavored sample peaked in acceptability at the 0.003% color level then declined markedly. Note that, as in the case of the beverages, depending upon the particular color/flavor level combination examined, a decrease in acceptability due to a reduction in color may or may not be compensated by increases in flavor.

(2) **Acceptability of color** was significantly affected by color level ($F = 16.13$, df = 3,87, $p < 0.001$), as shown in Figure 6. Color levels of 0.003% and 0.006% had equal acceptability, while acceptability decreased at either end of the color range.

(3) **Acceptability of flavor** was significantly affected by both color level ($F = 5.87$, df = 3,87, $p < 0.005$) and flavor level ($F = 24.58$, df = 2,58, $p < 0.001$), although the effect of flavor level appears to be primarily due to the difference between the unflavored and flavored samples (Figure 7).

(4) **Ratings of flavor intensity**, illustrated in Figure 8 were significantly affected by both flavor level ($F = 49.92$, df = 2,58, $p < 0.001$) and color level ($F = 15.37$, df = 3,87, $p < 0.001$), with perceived intensity of lemon flavor increasing markedly with increasing levels of yellow colorant.

A comparison of the above results with data obtained in the masking condition confirmed the finding that color cues under normal lighting conditions, did, in fact, have significant effects on overall acceptability, flavor acceptability, and flavor intensity judgments. The judgments of those qualities were not affected by color level under the red lighting condition as they were under normal lighting conditions. In addition, in judgments of overall acceptability and flavor acceptability, the flavor at the low end of the flavor range was rated higher and the flavor at the high end of the range was rated lower under the masking conditions than under the normal conditions. This can be interpreted as being the result of heightened awareness of the flavor of the cakes under the color masking condition.

Correlations among the four psychological responses to the lemon cake samples are shown in Table 5. It can be seen that ratings of flavor acceptability were most highly correlated with overall acceptability, as was found in the case of the beverages. Flavor intensity and color acceptability were also highly correlated with overall acceptability, and the magnitudes of the correlations were very similar. The two

Table 5—Correlations among subjective responses to lemon cakes [all correlations were significant (N = 800, p = 0.001)]

	Acceptability of color	Acceptability of flavor	Flavor intensity
Overall acceptability	0.505	0.756	0.520
Acceptability of Color		0.347	0.288
Acceptability of Flavor			0.698

—Continued on page 1415

flavor dimensions were highly correlated with each other, but not with the color dimension.

CONCLUSION

THE RESULTS from these experiments confirm intuition and previous findings that color is an important attribute of a food product in determining its acceptability. They also emphasize the fact that a product's color affects observers' judgments of other qualitative attributes of that product.

In the experiments examining masking and atypical color/flavor combinations (Experiments I and II), color was shown to be a critical cue in flavor identification, as shown previously by Moir (1936), Kanig (1955), and Hall (1958). Furthermore, it was shown that atypical colors have the effect of inducing flavors characteristically associated with that color.

In the experiments in which products varied in colorant and flavorant concentrations, the results indicated that, while flavor level could be adjusted to offset reduced color levels in some circumstances, this was not the case throughout the color range, and that a certain level of color was very important to consumers. In fact, warnings about the safety of the colorants used in the products had no detrimental effect on their ratings of the perceived acceptability of the product. Both physical color level and flavor level were significant factors in determining overall acceptability and sometimes interacted in affecting the consumers' response to the product. Color level was also shown to directly affect judgments of flavor intensity. Finally, it was found that in spite of the important effects of color on food quality judgments, in the purely subjective domain overall acceptability is more closely associated with the acceptability of the flavor of the product than with the acceptability of its color.

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